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[List of Attached Documents]

[Article]	Specification	1 copy
[Article]	Drawings	1 copy
[Article]	Abstract of the Description	1 copy

[Designation of document] Claims

[Claim 1]

A robot control apparatus equipped with a pendant to be manipulated by a teacher, for controlling the operation of a robot on the basis of an operation command from the pendant, comprising:

a detecting device for detecting the position of the teacher;

a signal processing unit for receiving a signal from the detecting device to produce the position information of the teacher; and

a limited speed selecting unit for selecting the operating speed of the robot on the basis of the position information, wherein

the robot is controlled at the maximum operating speed selected by the limited speed selecting unit on the basis of the operation command from the pendant.

[Claim 2]

A robot control apparatus equipped with a pendant to be manipulated by a teacher, for controlling the operation of a robot on the basis of an operation command from the pendant, comprising:

a robot position computing unit for computing the position of a tip portion of a working tool of the robot; and

a limited speed selecting unit for selecting the operating speed of the robot on the basis of an output from the robot position computing unit, wherein

the robot is controlled at the maximum operating speed selected by the limited speed selecting unit on the basis of the operation command from the pendant.

[Claim 3]

A robot control apparatus equipped with a pendant to be manipulated by a teacher, for controlling the operation of a robot on the basis of an operation command from the pendant, comprising:

a detecting device for detecting the position of the teacher;

a signal processing unit for receiving a signal from the detecting device to produce the position information of the teacher;

a robot position computing unit for computing the position of a tip portion of a working tool of the robot; and

a limited speed selecting unit for selecting the operating speed of the robot on the basis of outputs from the signal processing unit and the robot position computing unit, wherein

the robot is controlled at the maximum operating speed selected by the limited speed selecting unit on

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the basis of the operation command from the pendant.

[Claim 4]

The robot control apparatus according to any one of claims 1 to 3, wherein

the pendant displays an operating speed which is selected by the limited speed selecting unit.

[Designation of Document] Specification

[Title of the Invention] ROBOT CONTROL APPARATUS AND ROBOT SYSTEM

[Technical Field]

[0001]

This invention relates to a robot control apparatus for giving and assuring safety of a teacher in access to a robot in his pendant operation.

[0002]

[Background Art]

Now referring to the drawing, an explanation will be given of a conventional robot control apparatus. Fig. 4 is a view showing the configuration of the conventional robot control apparatus.

In Fig. 4, reference numeral 101 denotes a robot connected to a robot control apparatus 105. A working tool 102 for working is attached to the tip of a wrist of the robot 101. The robot control apparatus 105 is connected to a pendant 106 employed to conduct the editing such as registering of a working program, or changing of a registered working program by operating the robot 101, performing registering of a position thereof or registering of a work. The robot control apparatus includes a safety shelf surrounding the operating range of the robot 101, a safety shelf door 108 to a gateway

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to the safety shelf, and a safety shelf door opening/closing detecting device 109 for detecting the opened/closed status of the safety shelf door 108. The safety shelf door opening/closing device 109 is connected to the robot control deice 105.

The working is done by controlling the robot 101 in a manner of moving the working tool 102 on the basis of the above working program for a work 104 fixed to a work holding device 103 installed in the vicinity of the robot 101.

[0003]

In the position registering of the robot 101 which is a part of the working program, a teacher manipulates the pendant 106 to operate the robot 101 so that the working tool 102 attached to the wrist is positioned at a prescribed position relative to the work 104 and the position is registered in a storage member not shown within a robot controlling device through the operation of the pendant 106. The changing of the registered position of the robot 101 can be executed likewise.

In order to assure the safety of the teacher, the procedure in teaching will be explained below.

The teacher changes the operation mode of the robot into a teaching mode and opens the safety shelf door 108 to enter the safety shelf 107.

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As regards the operation mode of the robot 101, its maximum operating speed of the robot in the teaching mode is limited by informing the robot control apparatus of the facts that the operation mode is in the teaching mode and the safety shelf door opening/closing detecting device 109 is producing an opened status signal of the safety shelf door 108.

The maximum operating speed in this teaching mode is limited to limited to 250 mm/sec according to requirements of standard etc. in an end effect unit. [0004]

Next, in order to position the working tool 102 to a prescribed position of the work 104 and to register or change a registration, the robot 101 is operated by manipulating the pendant 106. At this time, the teacher must pay an attention to the robot 101, working tool 102, work holding device 103, work 104 and not shown peripheral devices of these components.

Further, in order to assure the safety of the teacher himself from the operation of the robot 101 not intended by the teacher due to an erroneous manipulation of the pendant 106, as in the above-description, the maximum operating speed in the teaching mode is limited. Thus, the teacher performs the teaching at a position apart from the robot 101 or work 104 so that he can perform

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an evading action against the inadvertent operation of the robot 101 during teaching.

However, according to the shape and size of the work 104, the shape of the working tool 102, an the arrangement of the work holding device 103 and peripheral devices, as the case may be, the teacher must comes near the robot 101 or work 104 for teaching.

Further, when the robot 101 is close to the work 104, the teacher sets the maximum operation speed of the robot 101 to be small from the pendant in order to prevent the robot 101 from colliding with the work 104 even if an erroneous manipulation occurs.

On the contrary, when the robot 101 is far from the work 104, the teacher sets the maximum operation speed of the robot 101 to be large from the pendant, since the robot 101 does not collide with the work 104 even if an erroneous manipulation occurs.

[0005]

[Problems to be solved by the Invention]

However, when the teacher performs the teaching for the robot in access thereto, because of his desire in the improvement in an operation efficiency and forgetting of setting, as the case may be, he may operate the robot and perform the teaching without reducing the maximum operating speed of the robot. In this case, if the pendant

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is erroneously manipulated, the robot makes the operation not intended by the teacher so that the teacher is surprised. Where the robot further comes near the teacher, he does not have a time to evade it.

As described above, the conventional robot control apparatus has a problem that it is difficult to assure the safety of the operator when performing the teaching involved with the robot operation in access to the robot.

In view of these problems, this invention is accomplished. An object of this invention is to provide a robot control apparatus which can enhance the safety of a teacher by detecting the teaching in access to a robot to automatically reduce the operating speed of the robot, and assuring the time for an evading action to the teacher when the robot operates at the direction or speed not intended by the teacher owing to an erroneous manipulation of a pendant. Further, according to this invention, there is provided a robot control apparatus which can enhance the safety of preventing from being broken by an erroneous manipulation by automatically changing an operation speed of the robot in accordance with a distance relation between the work and the robot.

[Disclosure of the Invention]

[0006]

[Means for solving the Problems]

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In view of these problems, this invention is accomplished.

In order to solve the problems described above, this invention is constructed as follows.

According to claim 1, there is provided a robot control apparatus equipped with a pendant to be manipulated by a teacher, for controlling the operation of a robot on the basis of an operation command from the pendant, including:

a detecting device for detecting the position of the teacher;

a signal processing unit for receiving a signal from the detecting device to produce the position information of the teacher; and

a limited speed selecting unit for selecting the operating speed of the robot on the basis of the position information, wherein

the robot is controlled at the maximum operating speed selected by the limited speed selecting unit on the basis of the operation command from the pendant.
[0007]

According to claim 2, there is provided a robot control apparatus equipped with a pendant to be manipulated by a teacher, for controlling the operation of a robot on the basis of an operation command from the

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pendant, including:

a robot position computing unit for computing the position of a tip portion of a working tool of the robot; and

a limited speed selecting unit for selecting the operating speed of the robot on the basis of an output from the robot position computing unit, wherein

the robot is controlled at the maximum operating speed selected by the limited speed selecting unit on the basis of the operation command from the pendant.
[0008]

According to claim 3, there is provided a robot control apparatus equipped with a pendant to be manipulated by a teacher, for controlling the operation of a robot on the basis of an operation command from the pendant, including:

a detecting device for detecting the position of the teacher;

a signal processing unit for receiving a signal from the detecting device to produce the position information of the teacher;

a robot position computing unit for computing the position of a tip portion of a working tool of the robot; and

a limited speed selecting unit for selecting the

operating speed of the robot on the basis of outputs from the signal processing unit and the robot position computing unit, wherein

the robot is controlled at the maximum operating speed selected by the limited speed selecting unit on the basis of the operation command from the pendant.
[0009]

According to claim 4, there is provided the robot control apparatus according to any one of claims 1 to 3, wherein

the pendant displays an operating speed which is selected by the limited speed selecting unit.
[0010]

[Best Mode for Carrying Out the Invention]

Now referring to the drawings, an explanation will be given of various concrete embodiments of this invention.

(Embodiment 1)

Fig. 1 is a view of the configuration of a robot system illustrating a first embodiment of this invention.

In Fig. 1, reference numeral 1 denotes a robot connected to a robot control apparatus 9. A working tool 2 for working is attached to the tip of a wrist of a robot 1. The robot control apparatus 9 is connected to a pendant 10 employed to conduct the editing such as registering

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of a working program, or changing of a registered working program by operating the robot 1, performing registering of a position thereof or registering of a work. The robot control apparatus includes a safety shelf surrounding the operating range of the robot 1, a safety shelf door 6 to a gateway to the safety shelf, and a safety shelf door opening/closing detecting device 7 for detecting the opened/closed status of the safety shelf door 6. An output signal from the safety shelf door opening/closing device 7 is connected to the robot control apparatus 9.

A detecting device 8 is installed in the vicinity of the robot 1 and a work holding device 3. An output signal from the detecting device 8 is connected to the robot control apparatus 9. The detecting device 8, when pressure higher or lower than a prescribed value is detected, supplies a signal to the robot control 9. This detecting device 8 may be e.g. a safety mat.

[0011]

A robot system, before it operates, sets a first maximum operating speed and a second maximum operating speed in a teaching mode by the operation of the pendant 10 by a robot system builder. These speeds are stored in a storage member not shown.

The second maximum operating speed is lower than the first maximum operating speed. The first maximum

operating speed is usually 2500 mm/sec, but may be lower
than this value according to the condition such as the
use and robot operating range.

The operation of the robot 1 in the teaching mode,
and registering of its position and changing of the
registered position are executed in the same as the prior
art described above.

[0012]

Fig. 2 is a block diagram showing speed control for
executing this invention. The detecting device 8 serves
to detect the position of a teacher. A signal from the
detecting device 8 is supplied to a signal processing
unit 11. The signal processing unit 11 supplies the signal
read from the detecting device 8 to a limited speed
selecting unit 12. The limited speed selecting unit 12
supplies, to a speed calculating unit 14, the limited
speed selected according to the signal statue acquired
from the signal processing unit 11 and operating mode
designated from an operating unit not shown. By the
manipulation of the pendant 10 by the teacher, the pendant
10 supplies an operating command to the speed calculating
unit 14. The speed calculating unit 14 compares the
limited speed supplied from the limited speed selecting
unit 12 and the taught speed obtained from the operating
command from the pendant 10. If the limited speed $\geq$ the

taught speed, the speed override ratio = 1 is supplied to a command creating unit 15. If the limited speed < the taught speed, the speed override ratio = limited speed/taught speed is supplied to the command creating unit 15. The command creating unit 15 reads the taught data stored in the taught data storage area 13 and corresponding to the operating command from the pendant 10, acquires the operating speed obtained from the taught speed of the taught data supplied by the speed override ratio supplied from the speed override ratio calculating unit 14 and supplies the operating command created to realize this operating speed to a driving unit 16. The driving unit 16 performs the servo driving control by means of a position controller, speed controller, current amplifier, etc., thereby operating the robot 1.

[0013]

In the teaching mode, when the robot 1 is operated through the manipulation of the pendant 1, in order to operate the robot 1 largely, the operator can manipulate the pendant 10 outside the operating range of the robot 1. For this reason, even when an inadvertent operation of the robot occurs owing to an erroneous manipulation, since the maximum operating speed of the robot 1 in the teaching mode is limited by the first maximum speed, the teacher can take an evading action. Further, since the

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teacher is present outside the operating range of the robot 1, the teacher will be not injured by the robot 1.

Now, where the teacher performs the teaching in a nearer position to the robot 1, work holding device 3 or work 4 according to the shape and size of the work 4, shape of the working tool 2 and arrangement of the work holding device 3 and peripheral devices, the teacher is present on the detecting unit 8 so that his weight is applied to the detecting unit 8. Thus, the detecting unit 8 detects the resultant stress and supplies the corresponding signal to the robot control apparatus 9.
[0014]

The robot control apparatus 9 takes the signal from the detecting device 8 in the signal processing unit 11 through a signal input device not shown. The result therefrom is supplied to the limited speed selecting unit 12. Before the operation, the limited speed selecting unit 12 supplies the second maximum operating speed stored in the storage member not shown to the speed override ratio calculating unit 14. The override ratio calculating unit 14 calculates the speed override ratio with the second maximum operating speed as the limited speed on the basis of the speed data supplied from the taught data storage area 13. The command creating unit 15 creates the

operating command to give the operating speed of the speed data from the taught data storage area 13 multiplied by the speed override ratio calculated, thereby operating the robot 1 through the driving unit 16. The driving unit 16 includes a servo amplifier and a servo motor which are employed to drive the manipulator.

Thus, the robot 1 operates at a speed lower than the second maximum operating speed.

For this reason, the maximum operating speed of the robot, while the teacher performs the teaching in access to the robot 1, work holding 3 or work 4, is the second maximum operating speed. Thus, in this status, even when the operation of the robot 1 not intended by the teacher occurs owing to the erroneous manipulation of the pendant 10, the teacher can take the evading action.

[0015]

(Embodiment 2)

Fig. 5 is a block diagram of speed control according to the second embodiment of this invention. A driving unit 16 is provided with a position detector capable of detecting a position. On the basis of the signal from this position detector, a robot position calculating unit 17 calculates the present position of the robot. The limited speed selecting unit 12 selects the maximum speed on the basis of the outputs from the signal processing

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unit 11 and robot position calculating unit 17. The manner of selection will be explained below on the basis of a configuration view.

Fig. 3 is a view showing the configuration of a robot system showing the second embodiment of this invention.

In Fig. 3, reference numeral 1 denotes a robot connected to a robot control apparatus 9. A work 4a and a work 4b for which working is to be carried out are arranged on the left and right side of the robot 1, respectively. Reference numerals 8a and 8b denote a plurality of detecting devices. When a predetermined pressure or lower is applied to the detecting devices 8a and 8b, these detecting devices supplies signals to the robot control apparatus 9, respectively. In Fig. 3, the working tool, work holding device, safety shelf, and other peripheral devices are not illustrated.

[0016]

The robot system, before it operates, sets a first maximum operating speed, a second operating speed and a third operating speed in a teaching mode by the manipulation of the pendant 10 by a robot system builder. These speeds are stored in a storage member not shown of the robot control apparatus 9.

The second and third maximum operating speeds are set at lower than the first maximum operating speed. The

first maximum operating speed is usually 2500 mm/sec, but may be lower than this value according to the condition such as the use and robot operating region.

[0017]

The operation of the robot 1 in the teaching mode, and registering of its position and changing of the registered position are executed in the same as the prior art described above. The working by the robot 1 requires the teaching for the work 4a and the teaching for the work 4b. Therefore, the teaching for the work 4a gives a chance of teaching to the teacher in access to the work 4b. Likewise, the teaching for the work 4b gives a chance of teaching to the teacher in access to the work 4a.

In the teaching in access to the work 4a or work 4b, the teacher performs the teaching on the detecting device 8a or detecting device 8b. Therefore, the detecting device 8a or 8b supplies a signal to the signal processing unit 11 of the robot control apparatus 9. The result obtained therefrom is supplied to the limited speed selecting unit 12.

[0018]

The robot control apparatus 9 knows the position of an end effecter of the robot 1 on the basis of the information from the position detector of each servo axis. In response to the output from the signal processing unit

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11 having processed the signal supplied from the detecting device 8a or 8b, the limited speed selecting unit 12 selects the limited speed as follows.

1)   If the signal is produced from the detecting device 8a and the end effecter of the robot 1 is located on the side nearer to the work 4a than to the center of the robot 1, the limited speed is set at the third maximum operating speed.

2)   If the signal is produced from the detecting device 8b and the end effecter of the robot 1 is located on the side nearer to the work 4b than to the center of the robot 1, the limited speed is set at the second maximum operating speed.

3)   In a case other than the cases 1) and 2), the limited speed is set at the first maximum operating speed.

The limited speed thus selected is supplied to the speed override ratio calculating unit 14. Thus, the robot 1 is controlled so that it operates at the speed lower than the limited speed thus set.

[0019]

(Embodiment 3)

Now referring to Fig. 6, an explanation will be given of the third embodiment of this invention. In Fig. 6, it is intended to control the operating speed of the robot 1 on the basis of only the present position of the robot

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computed by the robot position computing unit 17.

By depressing the pendant 10, an operation command
of a speed is transmitted to the speed calculating unit
14. Usually, on the pendant portion, a speed key for
selecting one of three or so taught speeds of a robot
is arranged. By depressing the speed key, the teacher
can select a desired taught speed of the robot.

If the teacher desires to operate the robot in the
+ X axis direction of the robot coordinates, he depresses
the key of designating the movement to + X. The pendant
10 informs the speed calculating unit 14 of depressing
the +X key. The speed calculating unit 14 creates a speed
command according to the taught speed set at present.
The speed calculating unit 14 compares the speed command
Vp created on the basis of the command from the pendant
10 and the speed Vs selected by the limited speed selecting
unit 12. As a result of comparison, if Vp > Vs, the speed
calculating unit 14 supplies the speed command of Vs to
the command creating unit 15. If Vp < Vs, the speed
calculating unit 14 supplies the speed command of Vp to
the command creating unit 15. Further, the maximum speed
at present is displayed by the pendant 10 so that the
teacher can know the maximum speed.

In this way, the operating speed of the robot will
not exceed the speed selected by the limited speed

selecting unit 12.

[0020]

[Effects of the Invention]

As explained in the above, according to the robot control apparatus of the present invention, when a teacher is in access to a robot or a work holding device, namely, when he is operating the robot for teaching in an operation area of the robot, even if the robot makes the operation not intended by the teacher owing to an erroneous manipulation, since the robot is controlled in a low operating speed, it is possible to assure the time for an evading action to the teacher and to enhance the safety of the teacher so that the teacher is not so surprised.

Further, only when the wrist or the working tool of the robot is in access to the teacher standing to the robot, the maximum operating speed is reduced. Therefore, the safety of the teacher is enhanced. Further, if the robot goes away from a position for operating thereof, namely, if the robot goes away from the teacher, since the maximum operating speed is increased, the decrease of the teaching effect is reduced to the minimum.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a view of the configuration of a robot system illustrating a first embodiment of this invention.

[Fig. 2]

Fig. 2 is a block diagram of speed control according to this invention.

[Fig. 3]

Fig. 3 is a view of the configuration of a robot system illustrating a first embodiment of this invention.

[Fig. 4]

Fig. 4 is a view showing the configuration of a conventional robot control apparatus.

[Fig. 5]

Fig. 5 is a block diagram of the second embodiment of this invention.

[Fig. 6]

Fig. 6 is a block diagram of a third embodiment of this invention.

[Designation of Document] Abstract

[Abstract]

[Problem]

A robot control apparatus with great safety is provided by detecting access of a teacher to a robot and automatically reducing the operating speed of the robot when the teacher accesses the robot.

[Means for Solution]

The robot control apparatus equipped with a pendant (10) to be manipulated by a teacher, for controlling the operation of a robot on the basis of an operation command from the pendant (10), includes a detecting device (8) for detecting the position of the teacher; a signal processing unit (11) for receiving a signal from the detecting device to produce the position information of the teacher; and a limited speed selecting unit (12) for selecting the operating speed of the robot on the basis of the position information. The robot is controlled at the maximum speed set at the operating speed selected by the limited speed selecting unit (12) on the basis of the operation command from the pendant (10).

[Selected Drawing] FIG. 2

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[Fig. 2]

8:    DETECTING DEVICE

10:   PENDANT

11:   SIGNAL PROCESSING UNIT

12:   LIMITED SPEED SELECTING UNIT

13:   TAUGHT DATA STORAGE AREA

14:   SPEED CALCULATING UNIT

15:   COMMAND CREATING UNIT

16:   DRIVING UNIT

[Fig. 4]

8:    DETECTING DEVICE

10:   PENDANT

11:   SIGNAL PROCESSING UNIT

12:   LIMITED SPEED SELECTING UNIT

14:   SPEED CALCULATING UNIT

15:   COMMAND CREATING UNIT

16:   DRIVING UNIT

17:   ROBOT POSITION COMPUTING UNIT

[Fig. 5]

10:   PENDANT

12:   LIMITED SPEED SELECTING UNIT

14:   SPEED CALCULATING UNIT

15:   COMMAND CREATING UNIT

16: DRIVING UNIT

17: ROBOT POSITION COMPUTING UNIT

[Fig. 7]

41: CONTROL UNIT

43: CONTROL PROGRAM STORAGE MEMBER

44: DATA STORAGE MEMBER

44-1: POSITION STORAGE AREA

44-2: PERMITTED VALUE STORAGE AREA

45-1: POSITION DETECTOR INTERFACE

45-n: POSITION DETECTOR INTERFACE

47-1: INPUT UNIT

A1: POSITION MONITORING SIGNAL

47-2: OUTPUT UNIT

A2: ABNORMALITY SIGNAL, WARNING SIGNAL

48: PENDANT INTERFACE

49: DRIVING CIRCUIT INTERFACE

50: DRIVING POWER SOURCE DEVICE

51-1: DRIVING CIRCUIT

51-n: DRIVING CIRCUIT

52-1: MOTOR

52-n: MOTOR

53-1: POSITION DETECTOR

53-n: POSITION DETECTOR

[Fig. 8]

A1:   START

STEP 1:   THERE IS POSITION MONITORING SIGNAL ?

A2:   NO

A3:   YES

STEP 2:   POSITION MONITORING SIGNAL RISES ?

A4:   NORMAL

A5:   RISES

STEP 3:   STORE DETECTED POSITION IN DETECTOR IN
POSITION STORAGE AREA

STEP 4:   COMPUTE POSITION DIFFERENCE BETWEEN DETECTED
POSITION IN DETECTOR AND DETECTED POSITION STORED IN
POSITION STORAGE AREA

STEP 5:   PERMITTED VALUE: POSITION DIFFERENCE

STEP 6:   STOP ROBOT

A6:   END

[Fig. 9]

A1:   START

STEP 11:   THERE IS POSITION MONITORING SIGNAL ?

A2:   NO

A3:   YES

STEP 12:   POSITION MONITORING SIGNAL RISES ?

A4:   NORMAL

A5:   RISES

STEP 13:   CALCULATE COORDINATE POSITION ON THE BASIS OF
DETECTED POSITION IN DETECTOR

STEP 14:   STORE COORDINATE POSITION IN POSITION STORAGE
AREA

STEP 15:   CALCULATE COORDINATE POSITION ON THE BASIS OF
DETECTED POSITION IN DETECTOR

STEP 16:   CALCULATE   POSITION   DIFFERENCE   BETWEEN
COORDINATE POSITION AND DETECTED POSITION STORED IN
POSITION STORAGE AREA

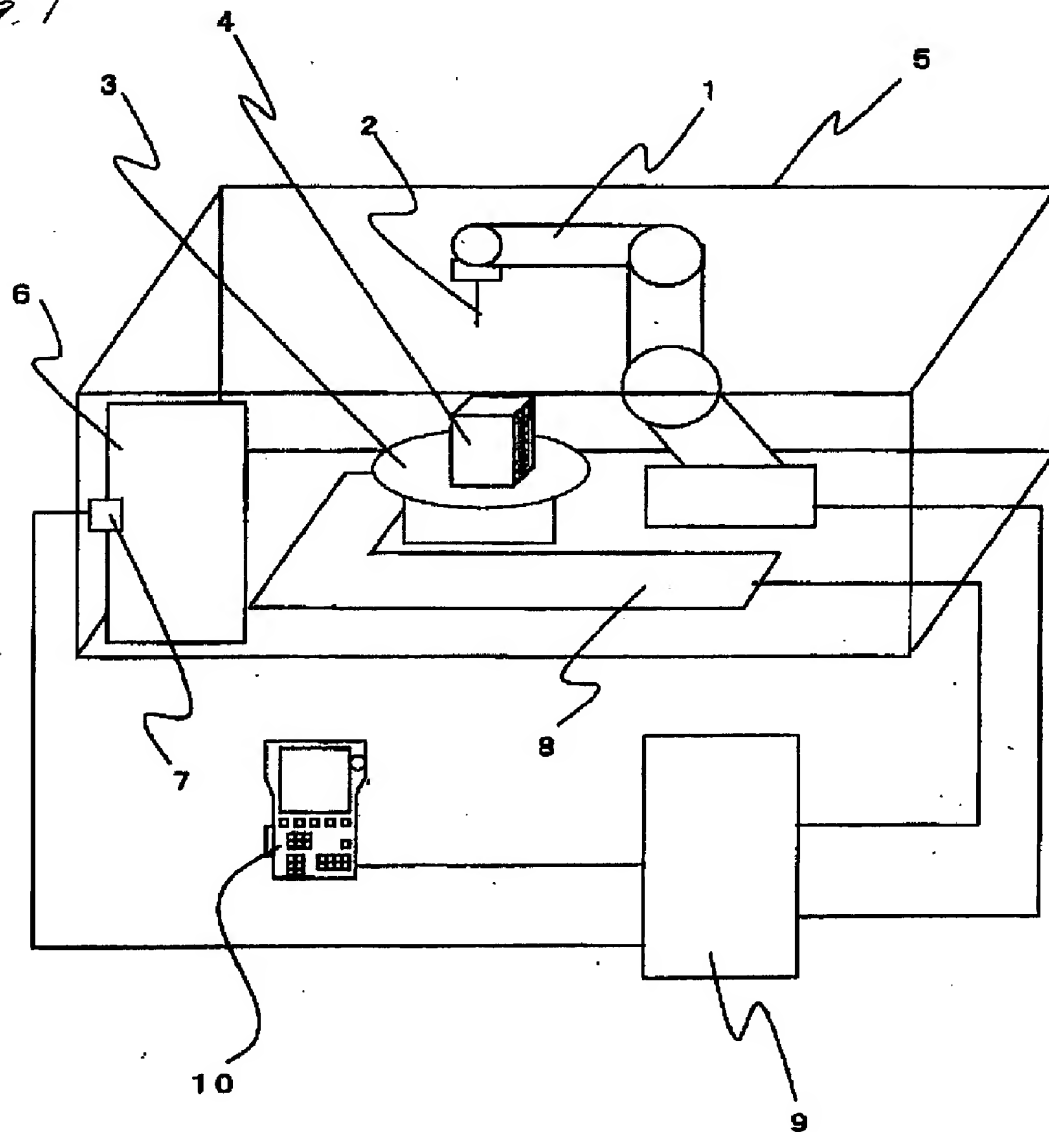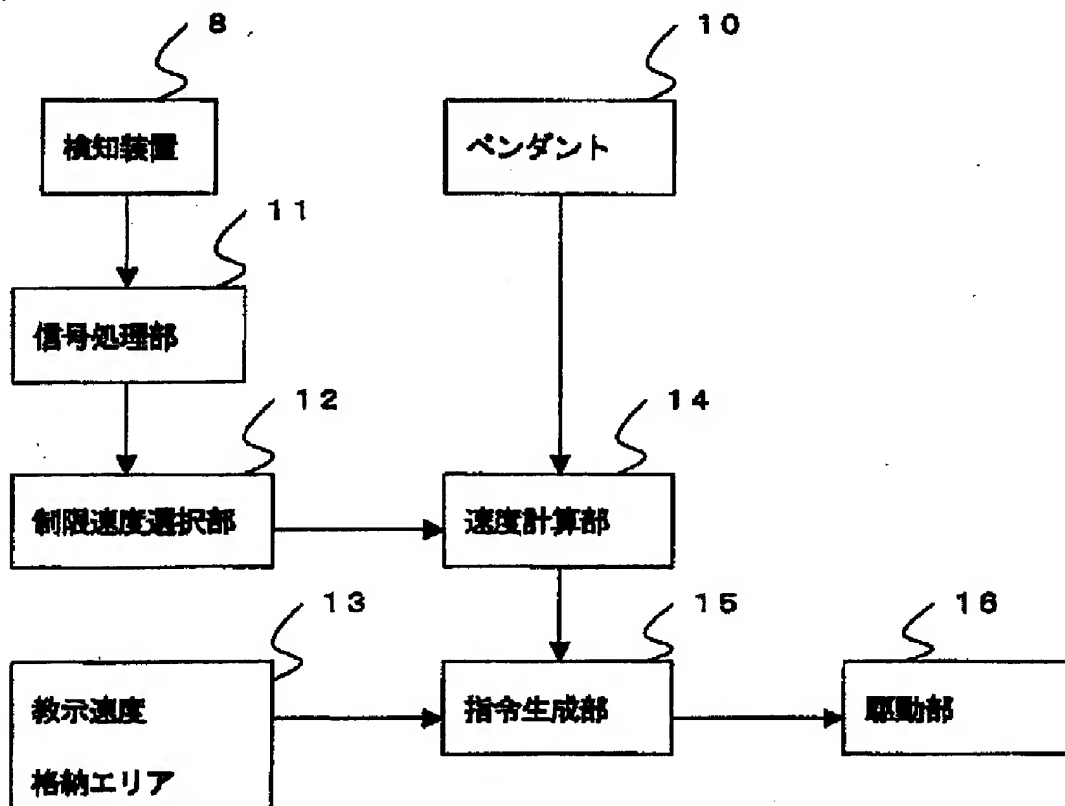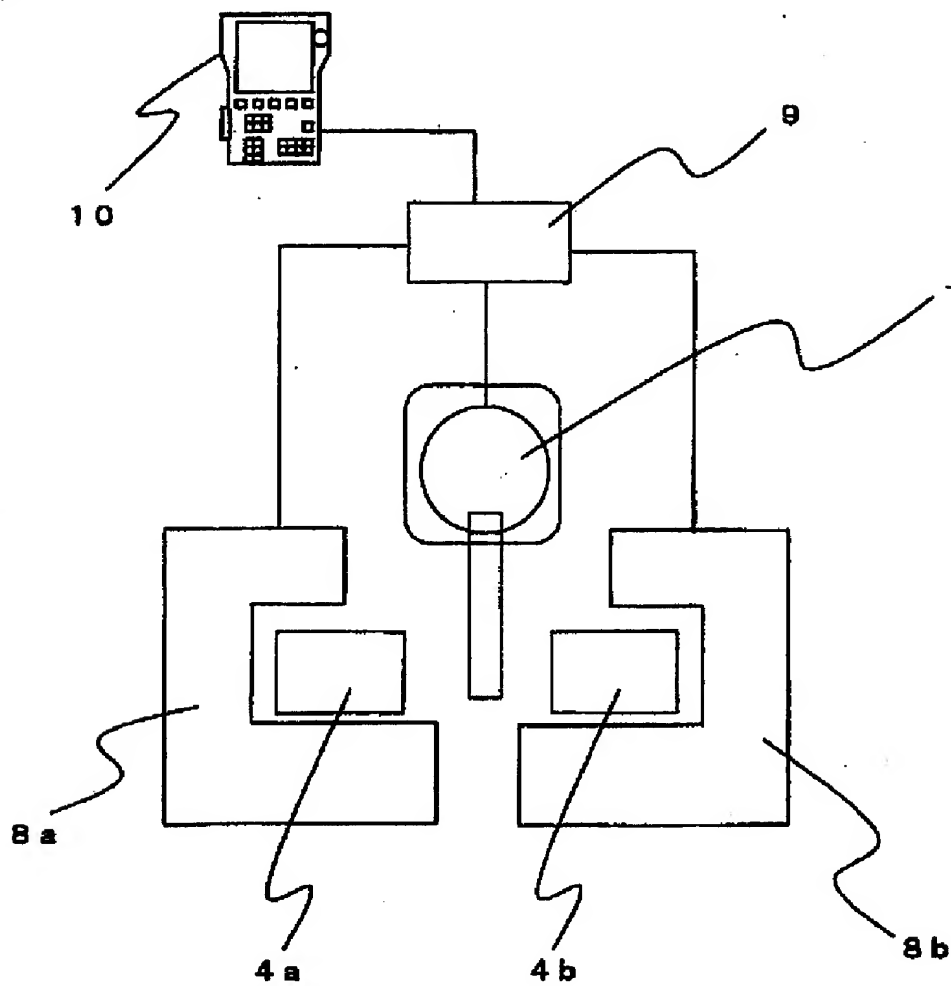STEP 17:   PERMITTED VALUE: POSITION DIFFERENCE

STEP 18:   STOP ROBOT
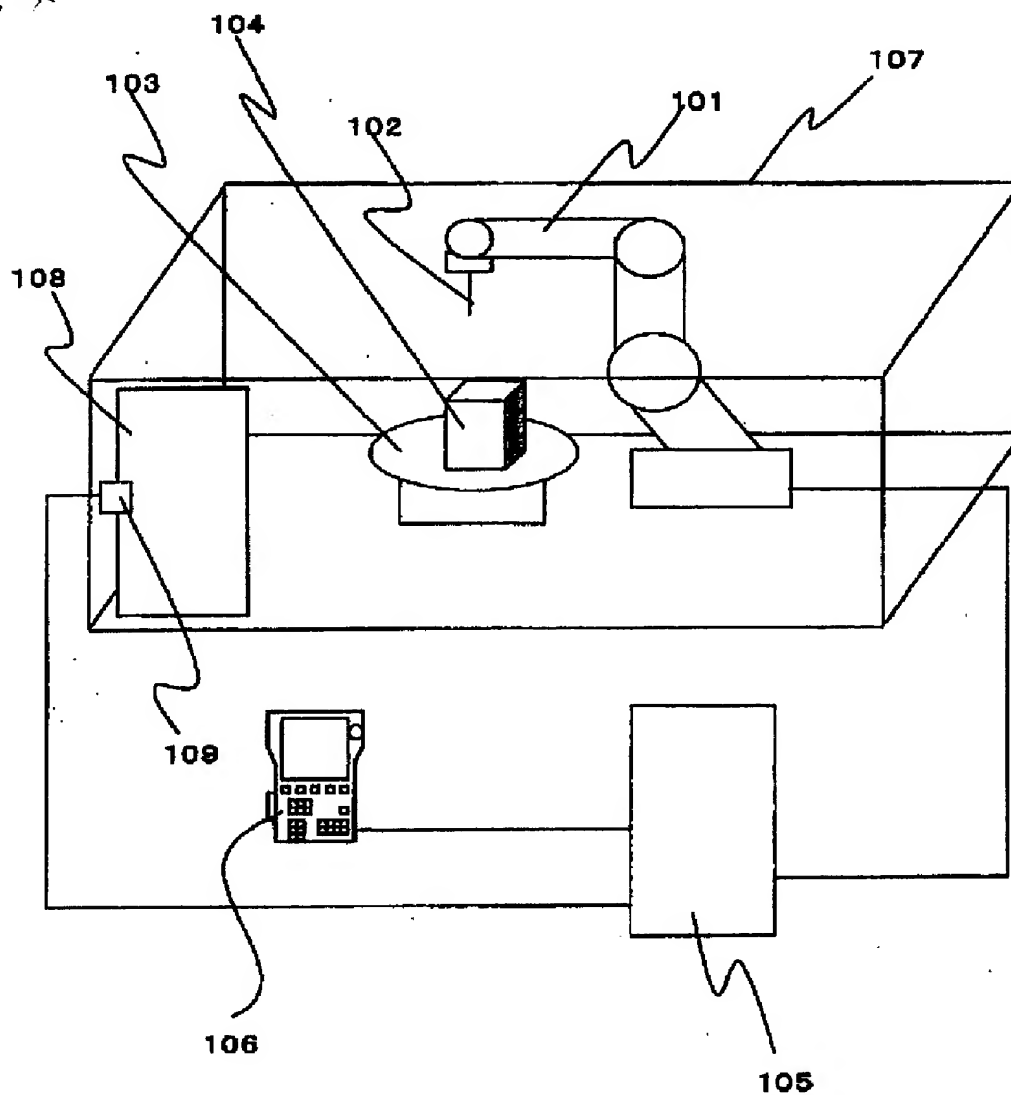
A6:   END

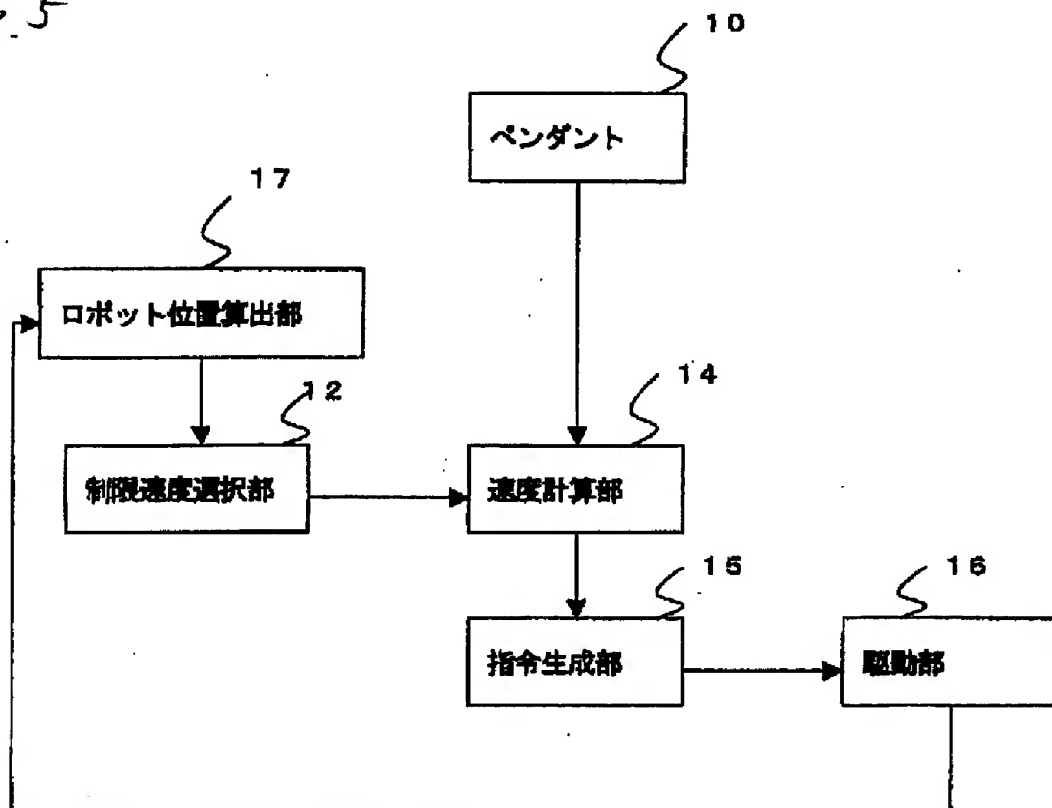【書類名】　　　　図面

【図１】

Fig. 1

【図２】

Fig. 2

【図３】

Fig. 3

【図４】

Fig. 4

【図５】

Fig. 5

【図6】

Fig. 6